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<b>(54) Title:</b> STRONG EARLY SEED-SPECIFIC GENE REGULATORY REGION		
<b>(57) Abstract</b> <p>Nucleic acid sequences and methods for their use are described which provide for early seed-specific transcription, in order to modulate or modify expression of foreign or endogenous genes in seeds, particularly embryo cells. The method finds particular use in conjunction with modifying fatty acid production in seed tissue.</p>		

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## STRONG EARLY SEED-SPECIFIC GENE REGULATORY REGION

## GOVERNMENT RIGHTS

The invention described herein was made in the course of work under grant number DE-FG02-94ER20133 from the U.S. Department of Energy. Therefore, the U.S. Government may retain certain rights in this invention.

## INTRODUCTION

## 1. Technical Field

A transcription regulatory region, comprising a nucleotide sequence, which promotes early seed-specific transcription of contiguous nucleotide sequences is provided.

## 2. Background

A large number of genes are known which are expressed only in developing seeds, or are expressed in developing seeds at much higher levels than in any other organ or tissue type. For the purposes herein, "gene expression" refers to synthesis of mRNA corresponding to a given gene. Thus, the amount of gene expression generally refers to the rate of transcription, or the rate of synthesis of the mRNA.

For convenience, in the context of this invention, we have generally assumed that differences in the steady-state level of mRNA accumulation reflects differences in the rate of synthesis of the mRNA. It is understood that in some cases changes in the steady-state level of mRNA could be caused by changes in the rate of mRNA degradation. However, it is considered unlikely that manipulation of promoter sequences, as taught herein, will generally affect the rate of mRNA degradation.

Much of the information about seed-specific gene expression has been derived from studies of genes encoding storage proteins (reviewed by Bevan et al., 1993). For instance, DNA sequences that confer embryo-specific expression by the soybean conglycinin promoter in transgenic plants have been identified (Chen et al., 1988). Similarly, the storage protein napin is one of the major protein components of *Brassica napus* L. (oilseed rape) seeds. A 152 bp fragment from the napin promoter directed strong expression of the  $\beta$ -glucuronidase reporter gene in mature tobacco seeds (Stalberg et al., 1996). Thus, the sequences that direct strong seed-specific expression of storage proteins are conserved between distantly related plant species. The napin promoter has been used to control expression of genes in transgenic plants designed to produce novel fatty acids (e.g., Voelker et al., 1996). However, because storage lipid accumulation begins substantially

before the maximal level of expression of the napin or other storage protein genes is reached (Post-Beittenmillar et al., 1992), the promoters of storage protein genes may not be preferred for controlling expression of genes related to storage lipid accumulation.

In the present invention, a preferred regulatory region (e.g., promoter, enhancer, silencer) for expression of genes directed toward modification of seed lipid composition, or other applications, would be derived from a gene that has a similar, or identical, temporal and tissue-specific pattern of expression to the genes that encode enzymes involved in seed storage lipid synthesis and accumulation. However, until recently, relatively few genes were known which are involved in lipid metabolism and are expressed in a seed-specific manner. The kappa hydroxylase from the Crucifer *Lesquerella fendleri* is one of the first examples of this class of genes. A promoter of the present invention normally controls the expression of the kappa hydroxylase from *L. fendleri*. Kappa hydroxylase is thought to be located in the endoplasmic reticulum where it catalyzes the introduction of a hydroxyl group into fatty acids attached to the sn-2 position of phospholipids. Since hydroxylated fatty acids are abundant in the seed storage lipids of *L. fendleri* but are not found to any appreciable extent in other organs or tissues, it seems likely that the gene is only expressed appreciably in seeds. The isolation of the

kappa hydroxylase gene from *L. fendleri* was described in U.S. Pat. Appln. Nos. 08/530,862 and 08/597,313, and PCT/US97/02187. Evidence was presented showing that the mRNA for the kappa hydroxylase was abundant in seeds but was not detectable in vegetative tissues. Here, we demonstrate that a regulatory region in the 5' direction from the coding sequence of the *L. fendleri* kappa hydroxylase is useful as a seed-specific promoter in plant species other than *L. fendleri*. We also show that the regulatory region can be used to cause early seed-specific expression of a gene other than the kappa hydroxylase (i.e., heterologous gene expression). Regulatory regions having the desired properties described herein should also be found upstream of other plant fatty acyl hydroxylase genes isolated and identified as disclosed in the parent applications.

#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide a transcription regulatory region for use in transgenic plants that exhibits seed-specific expression of a gene product.

It is a further object of the present invention to provide a transcription regulatory region for use in transgenic plants that exhibits an early level of expression of a gene product in developing seeds.

It is yet another object of the present invention to provide a transcription regulatory region for use in

transgenic plants that exhibits high-level expression of a gene product.

Isolated nucleic acids (e.g., DNA, RNA, cDNA, crRNA) are provided that comprise a transcription regulatory region (e.g., promoter, enhancer, silencer) from a plant fatty acyl hydroxylase gene. Preferably, the plant gene is a kappa hydroxylase gene and, more preferably, the kappa hydroxylase gene is from *Lesquerella*. The regulatory region may comprise a nucleotide sequence from SEQ ID NO:1. The regulatory region may comprise between about 500 nucleotides to about 2000 nucleotides, and may be capable of directing expression at a high level, at an early stage of development, in a seed-specific manner, or a combination thereof. The isolated nucleic acid may further comprise a sequence encoding for the native fatty acyl hydroxylase.

Recombinant nucleic acids (e.g., DNA, RNA, cDNA, crRNA) are provided that are comprised of the isolated nucleic acid described above and an operably linked non-native sequence to be transcribed. The sequence may be from the same plant species from which the regulatory region is derived or from a different species or genera; the sequence may even be from a bacterial, fungal, or mammalian gene. Preferably, the sequence is derived from a plant gene, especially one that is involved in seed lipid metabolism or seed development. The sequence may be in the sense or antisense orientation relative to transcription.

Expression constructs (e.g., DNA, RNA, cDNA, crRNA) are provided which are employed in manipulating plant cells to provide for early and/or seed-specific transcription. In particular, transcription regulatory regions from a gene encoding a fatty acyl hydroxylase are operably linked to other than the native or homologous gene, and introduced into a plant cell host for integration into the genome to provide for early and/or seed-specific transcription. The constructs provide for modulation of expression of endogenous products as well as production of exogenous products in the seed.

Transformed host cells, transgenic plants, and transgenic seeds are provided that contain an integrated or non-integrated nucleic acid, recombinant nucleic acid, or expression construct as described above. The host cell may be of bacterial, fungal, plant, animal, or similar origin. The transgenic plant may be *Arabidopsis*, *Brassica*, cotton, soybean, safflower, sunflower, tobacco, flax, peanut, or any other dicot species in which early seed-specific gene expression is desired. The regulatory region of the invention may also be useful in controlling seed-specific expression of genes in monocotyledonous species such as wheat, maize, rice, or the like. Transgenic seeds may be derived from similar plant species. Oil may be pressed, or otherwise extracted, or other materials such as proteins, carbohydrates, polyalkanoates, or secondary metabolites may



be extracted from the transgenic seed.

Kits are also provided containing a nucleic acid, recombinant nucleic acid, expression construct, host cell, or a combination thereof with directions for the use of the aforementioned to produce a transgenic plant or seed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a restriction map of plasmid pMON26112.

Figure 2 is a restriction map of plasmid pMON17227.

Figure 3 shows a partial nucleotide sequence of genomic clone pLesqtot containing the promoter region and coding region of the kappa hydroxylase gene from *L. fendleri*. The clone (3670 bp of continuous nucleotide sequence, SEQ ID NO:1) encodes a 2217 bp 5' untranslated region (i.e., sequence preceding the initiating ATG codon), an 1152 bp open reading frame, and a 302 bp 3' untranslated region. The HindIII and EcoRI sites used in subcloning are indicated with double underlines. The ATG that corresponds to the first translated codon of the kappa hydroxylase is underlined.

Figure 4 is a restriction map of plasmid pBI-pLesq-GUS.

Figure 5 is a restriction map of pMON17227-pLesq-GUS.

#### DETAILED DESCRIPTION OF THE INVENTION

In accordance with the subject invention, expression constructs are provided which allow for modification of

transcription in seeds, particularly in embryos during seed maturation. The expression constructs comprise a regulatory region (e.g., promoter, enhancer, silencer) associated with seed formation, preferably in association with embryogenesis and seed maturation.

Downstream from and under the transcriptional regulation of the kappa hydroxylase regulatory region will be a sequence of interest which will provide for modification of the phenotype of the seed, by modulating the production of an endogenous product, as to amount, relative distribution, timing or the like, or production of an exogenous expression product to provide for a novel function or product in the seed. The construct will preferably provide for a polyadenylation and/or a termination region, so as to provide an expression cassette into which a gene may be introduced.

Conveniently, transcriptional initiation and termination regions may be provided separated in the direction of transcription by a linker or polylinker having one or a plurality of restriction sites for insertion of the gene to be under the transcription regulation of the regulatory region(s). Usually, the linker will have from 1 to 10, more usually from about 1 to 8, preferably from about 2 to 6 restriction sites. Generally, the linker will be fewer than 100 bp, frequently fewer than 60 bp and generally at least about 5 bp. For an insert generated by nucleic

acid amplification, the insert may be linked to a regulatory region by techniques such as, for example, restriction enzyme digestion, direct blunt-end ligation, ligation-independent cloning (LIC), and ligation to a single 3'-overhang of a thymidine residue (U.S. Pat. No. 5,487,993).

The transcription regulatory region of this invention may be foreign, or heterologous to the host. By foreign is intended that the regulatory region is not found in the host into which the regulatory region is introduced. Of particular interest are those transcription regulatory regions associated with the seed-specific kappa hydroxylase gene, especially that of *L. fendleri*.

A transcription regulatory region may be used for varying the phenotype of seeds. Various changes in phenotype are of interest. These include modifying the fatty acid composition in seeds, that is changing the ratio and/or amounts of the various fatty acids, as to length, unsaturation, hydroxylation, epoxidation, or the like. Thus, the fatty acid composition may be varied by introducing enzymes which modify the fatty acids to produce fatty acids which are not normally found in the host plant. It may also be desirable to use the promoter of this invention to produce proteins that are directly useful in their own right, such as proteins that have catalytic properties for industrial use. Alternatively, one may provide various products from sources other than plants such as, for

example, mammals, fungi, archaeabacteria, and eubacteria. Indeed, the transcriptional initiation region of this invention may be generally used to produce any protein of interest in a seed of a plant host.

An expression cassette may include in the 5'→3' direction of transcription, a transcriptional initiation region, a nucleotide sequence of interest, and a transcriptional termination region functional in plants. In many, but not all, cases the expression cassette may also include translation initiation and termination sequences (i.e. a transcriptional/translational cassette). One or more introns may also be present.

The nucleotide sequence may usually have any open reading frame encoding at least part of a peptide of interest (e.g., an enzyme), or a sequence complementary to a genomic sequence (e.g., antisense), where the genomic sequence may be an open reading frame, an intron, a non-coding leader sequence, or any other sequence where the complementary sequence will inhibit transcription, messenger RNA processing (e.g., splicing), or translation. The nucleotide sequence of interest may be synthetic, naturally derived, or a combination thereof; the nucleic acid may be purified from a natural source (e.g., bacteria), a reaction mixture comprising template and a polymerase (producing DNA, cDNA or cRNA), or chemical synthesis.

In preparing the expression cassette, the various

nucleotide fragments may be manipulated, so as to provide for nucleotide sequences in the proper orientation and, as appropriate, in the proper reading frame. Towards this end, adapters or linkers may be employed to join the nucleotide fragments or other manipulations may be involved to provide for convenient restriction sites, removal of superfluous nucleotides, removal of restriction sites, or the like. For this purpose, in vitro mutagenesis, primer repair, restriction, annealing, resection, ligation, or the like may be employed, where insertions, deletions, inversions, or substitutions (e.g., transition, transversion), may be involved.

The termination region which is employed will be primarily chosen for convenience, since the termination regions appear to be relatively interchangeable. The termination region may be native to the transcriptional initiation region, may be native to the nucleotide sequence of interest, or may be derived from another source. Convenient termination regions are available from the Ti-plasmid of *A. tumefaciens*, such as the octopine synthase and nopaline synthase termination regions.

The nucleic acids and constructs of the invention may further comprise sequences that permit propagation and selection of the constructs in a foreign host. Optionally, an origin of replication and a selectable marker may be included in the nucleic acid or construct. The origin of

replication would preferably be derived from a microbe (e.g., bacteria, fungi), but may also be derived from a DNA or RNA virus. The selectable marker may be operative in prokaryotes and/or eukaryotes, and confer resistance to antibiotics such as, for example: ampicillin, hygromycin, kanamycin, neomycin, puromycin, tetracycline, or the like.

By appropriate manipulations, such as restriction, digesting back or filling in overhangs to provide blunt ends, ligation of linkers, or the like, complementary or flush ends of the fragments can be provided for joining and ligation.

In carrying out the various steps, cloning is employed, so as to amplify the amount of DNA and to allow for analyzing the DNA to ensure that the gene manipulations have occurred in a proper manner. A wide variety of cloning vectors are available, where the cloning vector includes a replication system functional in *E. coli* and a marker which allows for selection of the transformed cells. Illustrative vectors include pBR332, the pUC series, the M13 mp series, pACYC184, etc. Thus, the sequence may be inserted into the vector at an appropriate restriction site(s), the resulting plasmid used to transform the *E. coli* host, the *E. coli* grown in an appropriate nutrient medium, the cells harvested and lysed, and the plasmid recovered. Analysis may involve sequence analysis, restriction analysis, induction of expression, electrophoresis, or the like. After each

manipulation, the DNA sequence to be used in the final construct may be restricted and joined to the next sequence, where each of the partial constructs may be cloned in the same or different plasmids.

Depending upon the manner of introduction of the transcription construct into the host plant, other nucleotide sequences may be required. For example, when using the Ti- or Ri-plasmid for transformation of plant cells, as described below, at least the right border and frequently both the right and left borders of the T-DNA of the Ti- and Ri-plasmids will be joined as flanking regions to the transcription construct. The use of T-DNA for transformation of plant cells has received extensive study and is amply described in Fraley et al. (1986) and Lindsey (1996).

A variety of techniques are available for the introduction of nucleic acids into a plant cell host. These techniques include transformation with Ti-DNA employing *A. tumefaciens* or *A. rhizogenes* as the transforming agent, protoplast fusion, injection, electroporation, etc. (reviewed by Lindsey, 1996). For transformation with *Arobacterium*, plasmids can be prepared in *E. coli* which plasmids contain DNA homologous with the Ti-plasmid, particularly T-DNA. The plasmid may or may not be capable of replication in *Arobacterium*, that is, it may or may not have a broad spectrum prokaryotic replication system (e.g.,

RK290) depending in part upon whether the transcription construct is to be integrated into the Ti-plasmid or be retained on an independent plasmid. By means of a helper plasmid, the transcription construct may be transferred to *A. tumefaciens* and the resulting transformed organism used for transforming plant cells.

Conveniently, explants may be cultivated with *A. tumefaciens* or *A. rhizogenes* to allow for transfer of the expression cassette to the plant cells, the plant cells dispersed in an appropriate selective medium for selection, grown to callus, shoots grown and plantlets regenerated from the shoots by growing in rooting medium. The *Agrobacterium* host will contain a plasmid having the vir genes necessary for transfer of the T-DNA to the plant cells and may or may not have T-DNA. For injection and electroporation, disarmed Ti-plasmids (lacking the tumor genes, particularly the T-DNA region) may be used to introduce genes into the plant cell.

The cells which have been transformed may be grown into plants and either pollinated with the same transformed strain or different strains, and the resulting hybrid having the desired phenotypic characteristic identified. Two or more generations may be grown to ensure that the subject phenotypic characteristic is stably maintained and inherited and then seeds harvested to ensure the desired phenotype or other property has been achieved.

As a host cell, any plant variety may be employed which



provides a seed of interest. Thus, for the most part, plants will be chosen where a seed-specific product of interest is involved. Seeds of particular interest include the oil seeds, such as from *Arabidopsis*, *Brassica*, cotton, soybean, safflower, sunflower, tobacco, flax, peanut, or the like. Seeds of species such as wheat, maize, or rice may also be of interest.

The nucleotide sequence that comprises the promoter of this invention contains more than 2000 nucleotides. Based on the analysis of other plant promoters it seems likely that a substantially smaller region of sequence contained within the promoter of this invention would exhibit similar properties. For instance, as noted above, a 152 bp fragment from the napin promoter directed strong expression of the  $\beta$ -glucuronidase reporter gene in *B. napus* and tobacco seeds (Stalberg et al., 1996). Thus, we envision that a subsequence of a few hundred nucleotides or less may be found to have the same or similar properties as the full sequence disclosed here.

This subsequence may be identified by the kinds of experiments exemplified in the work of Stalberg et al. (1996) and others, such as those cited in the review by Bevan et al. (1993). The minimal promoter sequence can be identified by successively removing nucleotides from the promoter sequence (i.e. truncation) and comparing the activity of the modified promoter with that of the native

promoter. In addition, linker scanning or saturation mutagenesis may be used to produce the modified promoter. The promoter activity that may be assayed include, for example, the amount of transcription, the temporal specificity of transcription (i.e., early), the spatial specificity of transcription (i.e., seed), or a combination thereof of the kappa hydroxylase promoter. In a similar manner, enhancer or silencer sequences may be identified and modified. An enhancer or silencer sequence would not determine the position of transcription initiation, but could function in either orientation relative to the promoter and could be located at some distance from the promoter; an enhancer would increase transcription from an operably linked promoter and a silencer would decrease transcription from an operably linked promoter, presumably due to the presence of a cognate binding factor that recognizes the enhancer or silencer sequence. An enhancer binding factor would be expected to be present in early seed tissues whereas a silencer binding factor would be expected to be present in tissues other than seed or at times other than early development. The promoter, enhancer, silencer, or a combination thereof may be responsible for early seed-specific transcription by the kappa hydroxylase regulatory region. The promoter, enhancer, and/or silencer modules identified by genetic manipulation may be combined with native sequences or heterologous regulatory sequence from

other genes, preferably plant genes.

Computer comparison of 5' untranslated regions that are conserved between different plant fatty acyl hydroxylase genes may also be used to identify transcription regulatory regions (Gribskov and Devereux, 1991). Regulatory regions may also be identified by searching for consensus sequences that would be recognized by a known transcription binding factor, often such consensus sequences will exhibit dyad symmetry. The function of such putative regulatory regions may be confirmed by gel retardation or nuclease protection.

An assay for identifying a transcription regulatory region will typically involve fusing the region to a suitable reporter gene, such as the *E. coli*  $\beta$ -glucuronidase, then introducing that reporter construct into transgenic plants and assaying the amount of  $\beta$ -glucuronidase activity, protein, or mRNA produced (see Gallagher, 1992). Other reporter genes may be used, for example, alkaline phosphatase, chloramphenicol acetyltransferase, luciferase,  $\beta$ -galactosidase, green fluorescent protein, or derivatives thereof. Preferably, the assays are performed on stably transformed plants, but useful information may sometimes be gained by assaying tissues which have been transiently transformed with the constructs by particle bombardment or the like. Thus, many derivatives of the regulatory region disclosed herein are envisioned which would have similar or equal levels of activity. In addition, it is envisioned

that many nucleotide changes in the sequence of the transcription regulatory region or a derivative, will have equivalent activity. Thus, deletions, insertions, inversions, and/or substitutions in the disclosed nucleotide sequence may produce derivatives of the regulatory region with similar biological activity (e.g., amount of transcription, early transcription, seed-specific transcription). Preferably, a functionally equivalent derivative of SEQ ID NO:1 would comprise at least 2000 bp, at least 1600 bp, at least 1400 bp, at least 1200 bp, at least 1000 bp, at least 800 bp, at least 600 bp, at least 400 bp, at least 200 bp, at least 100 bp, or at least 50 bp.

The following examples are offered by way of illustration and not by way of limitation.

#### EXAMPLES

Abbreviations: X-Gluc (5-bromo-4-chloro-3-indolyl- $\beta$ -D-glucuronic acid) and GUS ( $\beta$ -glucuronidase).

#### MATERIALS AND METHODS

##### Cloning Vectors

The binary Ti plasmid pBI121 was purchased from Clontech (Palo Alto, CA). The ColE1-derived vector pMON26112 was obtained from Monsanto and is shown in Figure 1. This plasmid, which contains the napin promoter from *Brassica napus*, replicates in *E. coli* where it confers

ampicillin resistance. The binary Ti plasmid pMON17227 (Figure 2) contains an origin of replication from pBR322 to permit replication in *E. coli*, a spectinomycin/streptomycin resistance gene for selection in bacterial hosts and the left and right borders of the Ti plasmid flanking the CP4 synthase gene for selection on glyphosate and a NotI cloning site upstream of the nopaline synthase gene terminator sequence. The plasmid pMON17227-pLesq-GUS is a binary Ti plasmid derived from pMON17227 as described below.

#### Measurement of GUS Activity

The protocol for detecting GUS activity was as follows. Tissues were incubated in staining buffer (50 mM KPO<sub>4</sub> buffer pH 7.0 containing 20% methanol, 0.5% Triton X-100, 1 mM potassium ferrocyanide, 1 mM potassium ferricyanide and 3 mM X-Gluc). Typically, the tissue was incubated in this solution for about 12 hours but, in some cases where the staining was strong, the tissue was removed sooner and staining was completed in a shorter time. Samples were placed in a vacuum chamber at 650 mm Hg for 2 min then incubated for 15 hours at 37°C. Following staining, samples were cleared by successive 5 min immersions in 20%, 40%, 60% and 70% ethanol.

GUS activity was quantitated visually as follows: non-activity was scored as 0, the highest level of GUS activity observed was scored as 4 with a quasi-logarithmic scale. Samples that were approximately 50% as darkly stained as

those given a rating of 4, were rated as 3; samples that were approximately 50% as darkly stained as those given a rating of 4, were rated as 3; samples that were approximately 50% as darkly stained as those given a rating of 3, were rated as 2; and samples that were approximately 50% as darkly stained as those given a rating of 2, were rated as 1.

#### EXAMPLE 1. SEED-SPECIFIC EXPRESSION OF FOREIGN GENES IN TRANSGENIC *ARABIDOPSIS THALIANA*

##### Isolation of a Seed-Specific Promoter from *L. fendleri*

Genomic DNA was prepared from young leaves of *L. fendleri* as described by Murray and Thompson (1980). A Sau3AI-partial digest genomic library constructed in the vector  $\lambda$ DashII (Stratagene, La Jolla, CA) was prepared by partially digesting 500  $\mu$ g of DNA, size selecting the DNA on a sucrose gradient (Sambrook et al., 1989), and ligating the DNA (12 kb average size) to the BamHI-digested arms of  $\lambda$ DashII. The entire ligation was packaged according to the manufacturer's conditions and plated on *E. coli* strain XL1-Blue MRA-P2 (Stratagene). This yielded  $5 \times 10^5$  primary recombinant clones. The library was then amplified according to the manufacturer's instructions. A fraction of the genomic library was plated on *E. coli* XL1-Blue and resulting plaques (150,000) were lifted to charged nylon

membranes (Hybond N<sup>+</sup>, Amersham, Arlington Heights, IL), according to the manufacturer's recommendations. DNA was crosslinked to the filters under UV with a Stratalinker (Stratagene).

Several clones carrying genomic sequences corresponding to the *L. fendleri* hydroxylase were isolated by probing the membranes with a cDNA clone of the *L. fendleri* kappa hydroxylase carried on plasmid pLesq2 (described in U.S. Pat. Appln. No. 08/530,862). The insert from plasmid pLesq2 was labeled with <sup>32</sup>P by random priming. The filters were prehybridized for 2 hours at 65°C in 7% SDS, 1 mM EDTA, 0.25 M Na<sub>2</sub>HPO<sub>4</sub> (pH 7.2), 1% BSA and hybridized to the probe for 16 hours in the same solution. The filters were sequentially washed at 65°C in solutions containing 2 X SSC, 1 X SSC, 0.5 X SSC in addition to 0.1 % SDS. A 4.5 kb HindIII/NotI fragment containing the complete coding sequence for the hydroxylase and approximately 2.2 kb of the 5' upstream region was subcloned into the corresponding sites of pBluescript KS (Stratagene) to produce plasmid pLesqtot, and the sequence of the promoter region determined completely using an automatic sequencer by the dideoxy chain termination method. Sequence data was analyzed using the computer software package DNASIS (Hitachi, Brisbane, CA).

Partial sequence of the insert in clone pLesqtot is shown in Figure 3 (SEQ ID NO:1). The sequence comprises 3670 bp of continuous DNA sequence. The clone encodes a

2217 bp untranslated region (i.e., nucleotides preceding the first ATG codon), an 1152 bp open reading frame, and a 302 bp 3' untranslated region. The open reading frame encodes a 384 amino acid protein with a predicted molecular weight of 44,370.

#### Construction of the Vector pBI101-pLesq-GUS and Transformation of *Arabidopsis*

In a first step, pLesqtot was cut with HindIII and EcoRI, and a 2.2 kb insert fragment was cloned into pBluescript KS. The resulting vector, pLesqprom, contains 2.2 kb of sequence upstream of the ORF in pLesqtot. The promoter fragment did not contain a BamHI site but the polylinker of pBluescript KS contains a BamHI site adjacent to the EcoRI cloning site. Thus, pLesqprom was then cut with HindIII and BamHI and the insert fragment purified by agarose gel electrophoresis. pBI121 was cut with the same enzymes to release the 35S promoter fragment. The HindIII/BamHI insert fragment of pLesqprom was then ligated into the corresponding sites of pBI121 to obtain the vector pBI-pLesq-GUS (Figure 4). pBI-pLesq-GUS was then introduced into *Agrobacterium tumefaciens* strain GV3101 by electroporation, and used to transform *Arabidopsis* plants.

Cells for electroporation were prepared as follows. GV3101 was grown in LB medium (10 g tryptone, 5 g yeast extract, 5 g NaCl per liter of water). A 250 ml culture was



grown to  $OD_{600} = 0.6$ , then centrifuged at 4000 rpm (Sorvall GS-A rotor) for 15 min. The supernatant was aspirated immediately from the loose pellet, which was gently resuspended in 500 ml ice-cold water. The cells were centrifuged as before, resuspended in 30 ml ice-cold water, transferred to a 30 ml tube, and centrifuged at 5000 rpm (Sorvall SS-34 rotor) for 5 min. This was repeated three times, resuspending the cells consecutively in 30 ml ice-cold water, 30 ml ice-cold 10% glycerol, and finally in 0.75 ml ice-cold 10% glycerol. These cells were aliquoted, frozen in liquid nitrogen, and stored at  $-80^{\circ}\text{C}$ .

Electroporation employed a GenePulser instrument (Bio-Rad, Hercules, CA) using cold 2 mm-gap cuvettes containing 40  $\mu\text{l}$  of cells and 1  $\mu\text{l}$  of DNA in water, at a voltage of 2.5 KV and capacitance of 25  $\mu\text{F}$ . The electroporated cells were diluted with 1 ml SOC medium (Sambrook et al., 1989, page A2) and incubated at  $28^{\circ}\text{C}$  for 2-4 hours before plating on LB medium containing kanamycin (50 mg/l).

*Arabidopsis* plants were transformed by the *in planta* transformation procedure essentially as described by Bechtold et al. (1993). Cells of *A. tumefaciens* GV3101(pBI-pLesq-GUS) were harvested from liquid cultures by centrifugation, then resuspended in infiltration medium at  $OD_{600} = 0.8$ . Infiltration medium was Murashige and Skoog macro and micronutrient medium (Sigma, St. Louis, MO) containing 10 mg/l 6-benzylaminopurine and 5% glucose.

Batches of 12-15 plants were grown for 3 to 4 weeks in natural light at a mean daily temperature of approximately 25°C in 3.5 inch pots containing soil. The intact plants were immersed in the bacterial suspension, then transferred to a vacuum chamber and placed under 600 mm of vacuum produced by a laboratory vacuum pump until tissues appeared uniformly water-soaked (approximately 10 min). The plants were grown at 25°C under continuous light ( $100 \mu\text{mol m}^{-2} \text{s}^{-1}$  irradiation in the 400 to 700 nm range) for four weeks. The seeds obtained from all the plants in a pot were harvested as one batch. The seeds were sterilized by sequential treatment for 2 min with ethanol followed by 10 min in a mixture of household bleach (Chlorox), water and Tween-80 (50%, 50%, and 0.05%), then rinsed thoroughly with sterile water. The seeds were plated at high density (2000 to 4000 per plate) onto agar-solidified medium in 100 mm petri plates containing 1/2 X Murashige and Skoog salts medium enriched with B5 vitamins (Sigma) and containing kanamycin at 50 mg/l. After incubation for 48 hours at 4°C to stimulate germination, seedlings were grown for a period of seven days until transformants were clearly identifiable as healthy green seedlings against a background of chlorotic kanamycin-sensitive seedlings. The transformants were transferred to soil and grown to maturity. More than 20 transformants were obtained.

### Analysis of Transgenic Plants

The activity of the kappa hydroxylase promoter was assayed by staining various tissues of the transgenic *Arabidopsis* plants for the presence of  $\beta$ -glucuronidase activity by staining with X-Gluc (5-bromo-4-chloro-3-indolyl- $\beta$ -D-glucuronic acid). Histochemical staining was carried out on leaves, stems, siliques, flowers and developing embryos isolated at different stages from transgenic *Arabidopsis* plants. *Arabidopsis* embryos from three transgenic plants were dissected out of their seedcoat, and staged from late-heart stage to late-cotyledon stage on plates containing MS-salts medium with 7.5 g/l agar, before being transferred to GUS staining buffer. Leaves, stems, and inflorescences were collected from transgenic plants and directly immersed in staining buffer.

The results obtained with three independent transgenic plants, designated 1 to 3, is shown in Table 1. It can be seen from these results that the kappa hydroxylase promoter caused the appearance of GUS activity as early as the torpedo stage embryo. The GUS activity persisted throughout subsequent development of the embryo. The amount of GUS activity in pBI-pLesq-GUS transgenic plants was compared with transgenic plants expressing the GUS gene driven by the promoter from the gene encoding the alpha subunit of the soybean beta-conglycinin (7S) gene (Hirai et al., 1994). p7S-GUS plants were chosen for their high level of GUS

expression. The *Lesquerella* promoter was active earlier than the 7S promoter. Onset of activity coincides with that of storage lipid accumulation in *Arabidopsis* (Table 1). The level of GUS activity in the transgenic plants containing the kappa hydroxylase promoter was at least as high as in the transgenic plants containing the soybean  $\beta$ -conglycinin promoter. There was no GUS activity in samples of leaves, stems, or pods of the transgenic plants. Thus, the kappa hydroxylase promoter can be used to cause seed-specific expression of foreign genes in transgenic plants.

Table 1. Histochemical staining of transgenic *Arabidopsis* plants expressing the GUS gene under the control of different seed-specific promoters.

Stage									
<i>Lesquerella kappa</i> hydroxylase promoter									
	A	B	C	E1	E2	E3	E4	E5	F
1	0	0	0	0	1	2	4	4	1
2	0	0	0	0	1	2	4	4	1
3	0	0	0	0	1	2	4	4	1
Soybean beta-conglycinin promoter (alpha subunit)									
1	0	0	0	0	0	0	2	4	0
2	0	0	0	0	0	0	2	4	0
3	0	0	0	0	0	0	2	4	0

A: leaf                      E1: embryo (heart stage)  
 B: stem                     E2: embryo (torpedo stage)  
 C: pod                      E3: embryo (cane-shaped embryo)  
                               E4: embryo (early cotyledon stage)  
                               E5: mature embryo

0: no detectable staining  
 4: highest intensity of staining detected among samples of the same tissue type  
 3: intensity of staining about 1/2 of the maximum intensity  
 2: intensity of staining about 1/4 of the maximum intensity  
 1: light staining, about 1/10 of the maximum intensity

## EXAMPLE 2. SEED-SPECIFIC EXPRESSION OF FOREIGN GENES IN TRANSGENIC *BRASSICA NAPUS*

### Construction of the Vector pMON17227-pLesq-GUS for Transformation of Canola

In a first step, the GUS gene was purified by cutting the vector pBI121 (Clontech) with SmaI and SacI. The insert fragment containing the GUS gene was cloned into the StuI and SacI sites of vector pMON26112, resulting in the vector pMON26112-GUS. In a second step, a HindIII/BamHI fragment from pLesqprom containing the *L. fendleri* kappa hydroxylase promoter was cloned into pMON26112-GUS cut with HindIII and BglII. The resulting vector (pMON26112-pLesq-GUS) was cut with NotI, and the insert fragment ligated to the vector pMON17227 cut with NotI. The final vector, pMON17227-pLesq-GUS (Figure 5) was used to introduce the *Lesquerella* promoter-GUS cassette into canola plants using *Agrobacterium*-mediated transformation.

### Transformation and Regeneration of *B. napus*

*Agrobacterium* strain ABI containing pMON17227-pLesq-GUS was used to transform *Brassica napus* cv Westar essentially as described by Fry et al. (1987). Briefly, seedlings are planted in Metro Mix 350 and grown in a growth chamber with these conditions: temperature day

15°C and night 10°C, light intensity 600  $\mu\text{mol m}^{-2}\text{s}^{-1}$ , 8 hours night, relative humidity 50%, and are transferred into 6 inch pots when they are 3 weeks old. Five-week-old Westar plants are harvested once the plants bolt, but prior to flowering (plants with up to 3 flowers may be harvested). The leaves and buds are removed and the 4-5 inches of stem below the flower buds are used as the explant tissue source. Just prior to inoculation, the stems are sterilized as follows: soak in 70% ethanol for 1 minute, soak in 38% Clorox for 20 minutes, rinse two times in sterile deionized water, and soak in two tablespoons of Captan 50-WP (ICI) plus 500 ml sterile water for 15 minutes.

#### *Agrobacterium* Preparation

*Agrobacterium* is streaked onto an LB plate containing spectinomycin 100 mg/l, Streptomycin 100 mg/l, chloramphenicol 25 mg/l, and kanamycin 50 mg/l (denoted LB-SSCK). Two days before inoculation, a 10  $\mu\text{l}$  loop of *Agrobacterium* is placed into a tube containing 2 mls of LB-SSCK and put onto a rotator to grow overnight. The day before inoculation, the *Agrobacterium* is subcultured, 200  $\mu\text{l}$  is placed in 2 ml of fresh LB-SSCK and returned to the rotator to grow overnight. On the inoculation day, the *Agrobacterium* is diluted 1:10 with MS liquid medium. An  $\text{OD}_{600}$  reading is taken, readings in the range of 0.2 to

0.4 are acceptable.

#### Explant Inoculation

Stems are cut into one quarter inch segments, noting the basal orientation of the stems. Explants are inoculated in a petri plate for 5 minutes with the 1:10 dilution of *Agrobacterium*; 5 ml *Agrobacterium* per 5 stems are used and the *Agrobacterium* is pipetted directly on top of the explants. *Agrobacterium* is aspirated off of the explants after the 5 minute inoculation time. Stem explants are cultured in the basal-side down orientation for an optimal shoot regeneration response on the co-culture plates, (1/10 MS medium with a 2 ml TXD liquid medium covered with sterile 8.5 cm filter paper). TXD medium contains 4.3 g Gibco MS medium, 2 ml of 500 x solution of Gamborg B5 mixture (Sigma), 8 ml p-chlorophenoxyacetic acid (0.5 mg/ml) 0.01 ml Kinetin (0.5 mg/ml), 30 g sucrose and water to one liter. Co-culture plates are put in clear plastic bags which are slit and placed at 25°C, 24 hours continuous cool-white light.

#### Tissue Selection and Regeneration

After a 2 day co-culture period, stem explants are moved onto MS medium containing 500 mg/l ticarcillin, 50 mg/l cefotaxime, and 1 mg/l benzylaminopurine (BAP) for a 3 day delay period; again plates are put in clear plastic



bags which are slit and placed at 25°C, 24 hours continuous cool-white light. After a three-day delay period, stem explants are moved onto MS 0.1 mM glyphosate selection medium containing glyphosate and the abovementioned levels of ticarcillin, cefotaxime, and BAP for three weeks. Then, the stem explants are moved onto the MS 0.1 mM glyphosate selection medium containing the same amounts of ticarcillin, cefotaxime, and BAP cited above plus 0.5 mg/l gibberellin (GA<sub>3</sub>) which was found to enhance shoot elongation, for another three week period. After these six weeks on glyphosate selection medium, green, normal developing shoots are excised from the stem explants. Shoots (4-5 shoots per plate) are placed in rooting medium [Gibco MS salts, vitamins, 3% sucrose containing the above levels of ticarcillin and cefotaxime and 2 mg/l indolebutyric acid (IBA)]. Root development begins to occur as early as one week after shoots go onto rooting medium. At the 2 week timepoint, shoots with a large root base are moved into 2 1/2 inch pots with potting soil (Metro Mix 350); flats are covered with the clear plastic domes so the shoots can elongate. All plants are placed in a growth chamber with the same conditions as described above for stock plant growth. When shoots are hardened off after 3-4 days, the plastic domes are cracked and several days later removed completely. The plants are grown in a growth chamber at

22°C in a 16 hr/8 hr light/dark cycle with light intensity  $220 \mu\text{E m}^2 \text{ S}^{-1}$  and after several weeks are transferred to the greenhouse.

#### Analysis of Transgenic Plants

Eighteen regenerated *B. napus* plants were examined for embryo-specific expression of the GUS gene using the same scale for expression levels as described in Example 1. Transgenic canola pods and seeds were collected at less than 10, 10, 16, 21, 28, 35 dpa and at maturity. Leaf, stem, pods and seed samples were stained for  $\beta$ -glucuronidase activity as described above. The results of the GUS assays are presented in Table 2.

Table 2. Histochemical staining of transgenic *B. napus* plants expressing the GUS gene under the control of different seed-specific promoters.

Stage										
	A	B	C	D1	D2	D3	D4	D5	D6	D7
1	0	0	0						1	1
2	0	0	0	3-4	3-4				2	0
3	0	0	0	3-4	3-4				1	1
4	0	0	0	3-4	3-4	3-4	3-4		1	0
5	0	0	0	3-4	3-4				1	1
6	0	0							1	0
7	0	0	0	3-4	3-4				1	0
8	0	0	0	3-4	3-4	3-4	3-4	3-4		
9	0	0	0	1	2				1	0
10	0	0	0	2	2	2				
11	0	0	0	2	3-4					
12	0	0	0	3-4	3-4					
13	0	0	0	3-4	3-4	3-4	3-4	4	2	1
14	0	0		3-4						
15	0	0	0		3-4					
16	0	0	0	3-4	3-4					
17	0	0	0	3-4	3-4					
18	0	0	0	3-4	3-4					
A: leaf				D1: seed 16 dpa			D5: mature seed			
B: stem				D2: seed 21 dpa			D6: seed: < 10 dpa			
C: pod				D3: seed 28 dpa			D7: seed: 10 dpa			
				D4: seed 35 dpa						

It is apparent from the results in Table 2 that a foreign gene fused to the kappa hydroxylase promoter is not expressed at significant levels in non-seed tissues, but is abundantly expressed in developing seeds. High levels of GUS staining were apparent as early as 16 days post-anthesis and the staining persisted throughout seed development. Thus, the kappa hydroxylase promoter is a useful promoter for causing the expression of foreign genes in plants. The promoter is particularly useful in applications where it is desirable to have the gene of interest transcribed at high levels an early stage of seed development and persist throughout seed development. Such applications include modification of seed lipid metabolism.

All publications and patent applications mentioned in this specification are indicative of the level of skill of those skilled in the art to which this invention pertains.

All publications and patent applications are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be obvious

to the skilled artisan that certain changes and modifications may be practiced within the scope of the appended claims.

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## SEQUENCE LISTING

- (1) GENERAL INFORMATION:
  - (i) APPLICANT: BROUN, Pierre  
SOMERVILLE, Chris
  - (ii) TITLE OF INVENTION: STRONG EARLY SEED-SPECIFIC GENE  
REGULATORY REGION
  - (iii) NUMBER OF SEQUENCES: 1
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    - (F) ZIP: 20005-3918
  - (v) COMPUTER READABLE FORM:
    - (A) MEDIUM TYPE: Diskette
    - (B) COMPUTER: IBM PC compatible
    - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
    - (D) SOFTWARE: MS Word
  - (vi) CURRENT APPLICATION DATA:
    - (A) APPLICATION NUMBER:
    - (B) FILING DATE:
    - (C) CLASSIFICATION:
- (2) INFORMATION FOR SEQ ID NO:1:



## (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 3670 nucleotides

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

AAGCTTTTGA GCTCATCAGT TACTCAGGAA GATTAAGTCT	40
TTGCTTGTTG TCTGATTTTC TTAAATACA TGAAGGATCG	80
GTTATGAATC TTCTTTTTTT GTGTTTGGG ATTATGAAGC	120
TGTCTTTGGA TATTAGTTGC GGTTATTAGC ATGCTTCTCT	160
TTTGTGTTTT GGGGATTATG AAGCAGGGTC TGTCTATGTA	200
ATGCATTTTG TTTGAAAAC CAGCTAATGC TAATGCAATT	240
TCTTTTGAAA CCTTTGTTAT GTTTTCGAAA ATATTGAATA	280
NGTTCTGTTA TGGATTATT TGCAAAAGCC ATTGATTAAA	320
TCAAACATTA CATAAGAACA ACATTCATTA TTAATAATT	360
AGAGATGCAA AACACAACAT TACATACAAC ATCAGTGACT	400
AATTATTGAG ACAAACAAC ATCACATACA CAAACATTCA	440
TCTCATACAT CACTTAGAGA GACACAAAAA GCAACCAAAC	480
ACAACTATTC CGGCAACAAC AATTAGCTTC ATACGTTTTG	520
CTTCTCCTTT CAAGCCTTCA ATCATCTTCT CACAGCCACG	560
AATCTGAGCC TTCAATAATA ACATTCTTC ATCGTGACAC	600
TTCTCACGGT TATGAATGTA AGCCTTTATG TCCTCTACTT	640
CTTCTACTAA AGACACATCA GTCCACTTCC AGGTGTGGAA	680
TCCTCCTCTT TTGAAATTTT TCTCACAGGT ATGGAATAAT	720
CTACCTAGGT TTTTGGAGT TCTTGAGGTT CTGATCACAA	760
CACGACATCC AAATCGACAG GTCTTAGGAA AACCACGATG	800

GTTATCATCT TCAAGCTCAC TGTCAAAGA GAAAAACGAG 840  
TTTGAAGAAG AAGAAGGCAT TATCAATTTC AGAGAATTTT 880  
GGAGAATTTT GAGAGATTGA GAATTGGGAA ATAAGAACCC 920  
TAATCCCCAA TTTATGAGAT TGAAAATATA TCCGTTAGAG 960  
AAGAAACATA ATGCTGTGCG TTTTAATTAG AAAAAATAGA 1000  
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TCGTTTGTT TAATTGTTGT TAAAAAAT TAAAACACCA 1120  
AAACGACGTC GTTTTGTTGT TATTACGGC CTTAAAACGG 1160  
ATTAAATCCA TAATCCGTCA GTCAACTAGG TTACGGATGG 1200  
TCAACGGCGT TTTTGCATAA CGGAGGCACA GTTCAGGCTT 1240  
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GGGATTTTTT GTTTATGATG TATTTGTCCC CGTCGGCTAT 1320  
TGTTTAGGCC GTTTTTCCTA TATATTGGAA ATAATTATTG 1360  
TCCAGACGAG TTAATTCTCC AACATATCAA GAAATGTTAC 1400  
AAAGAAGTGT TACAAAAATG TGTTACTAAG CCATAAACT 1440  
CAAAGCATAT ATCTTAGACC CTAAGCCTAA ACCCTAGAAC 1480  
TTTCTAGGAC GTTTATACCT TGTCCTTTCT TTAGTTTCCT 1520  
TTAAAGGCCT TCGTATTCAT AAGTTTTATT TTTGCTTAAT 1560  
ACTAACAATA GAAATAATCA ACATAAACTA GGTAAAGTCG 1600  
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TCATGAAATG GTGACAACTT TATTCTAGAG GTAACAGAAC 1760  
AAAAATATAG GAACAACACG TGTTGTTTCAT AACTACACG 1800  
TATAATACTC AAGAAGATGA ATCTTTATAA GAATTTAGTT 1840

TTCTCATGAA AACATAAAAA ATTTTGTCAA TTGAAAGTGA 1880  
 CAGTTGAAGC AAAGGAACAA AAGGATGGTT GGTGATGATG 1920  
 CTGAAATGAA AATGTGTCAT TCATCAAATA CTAAATACTA 1960  
 CATTACTTGT CACTGCCTAC TTCTCCTATT TCCTCCGCCA 2000  
 CCCATTTTGG ACCCACGAGC CTTCCATTTA AACCTCTCT 2040  
 CGTGCTATTC ACCAGAAGAG AAGCCAAGAG AGAGAGAGAG 2080  
 AGATTGTGCT GAGGATCATT GTCTTCTTCA TCGTTATTAA 2120  
 CGTAAGTTTT TTTTGACCAC TCATATCTAA AATCTAGTAC 2160  
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 GGTTACCCCC TCTTCCAAGA AATCAGAAAC TGAAGCCCTA 2280  
 AAACGTGGAC CATGTGAGAA ACCACCATT 2320  
 ATCTGAAGAA AGCAATCCCA CAGCATTGTT TCAAGCGCTC 2360  
 TATCCCTCGT TCTTTCTCCT ACCTTCTCAC AGATATCACT 2400  
 TTAGTTTCTT GCTTCTACTA CGTTGCCACA AATTACTTCT 2440  
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 TTCCTTCCTT CTCGTCCCTT ACTTCTCCTG GAAATACAGT 2640  
 CATCGTCGTC ACCATTCCAA CAATGGATCT CTCGAGAAAG 2680  
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 GTATGTTAAA TACCTCAACA ACCCTCTTGG ACGCATTCTG 2760  
 GTGTTAACAG TTCAGTTTAT CCTCGGGTGG CCTTTGTATC 2800  
 TAGCCTTTAA TGTATCAGGT AGACCTTATG ATGGTTTCGC 2840  
 TTCACATTC TTCCCTCATG CACCTATCTT TAAAGACCGA 2880

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ATTGACTGCT ATGATCTGCG TCTATGGAGT ACCGCTTTTG 3000  
ATAGTGAAC TTTTCCTTGT CTTGGTAACT TTCTTGCAAGC 3040  
ACACTCATCC TTCGTTACCT CATTATGATT CAACCGAGTG 3080  
GGAATGGATT AGAGGAGCTT TGGTTACGGT AGACAGAGAC 3120  
TATGGAATAT TGAACAAGGT GTTCCATAAC ATAACAGACA 3160  
CACATGTGGC TCATCATCTC TTTGCAACTA TACCGCATTA 3200  
TAACGCAATG GAAGCTACAG AGGCGATAAA GCCAATACTT 3240  
GGTGATTACT ACCACTTCGA TGAACACCG TGGTATGTGG 3280  
CCATGTATAG GGAAGCAAAG GAGTGTCTCT ATGTAGAACC 3320  
GGATACGGAA CGTGGGAAGA AAGGTGTCTA CTATTACAAC 3360  
AATAAGTTAT GAGGCTGATA GGGCGAGAGA AGTGCAATTA 3400  
TCAATCTTTT TTTCATGTTT TAGGTGTCTT GTTTAAGAAG 3440  
CTATGCTTTG TTTCAATAAT CTCAGAGTCC ATTTAGTTGT 3480  
GTTCTGGTGC ATTTTGCCTA GTTATGTGGT GTCGGAAGTT 3520  
AGTGTTCAAA CTGCTTCCTG CTGTGCTGCC CAGTGAAGAA 3560  
CAAGTTTACG TGTTTAAAAT ACTCGGAACG AATTGACCAC 3600  
AANATATCCA AAACCGGCTA TCCGAATTCC ATATCCGAAA 3640  
ACCGGATATC CAAATTTCCA GAGTACTTAG 3670

## CLAIMS:

1. A nucleic acid comprised of a transcription regulatory region from a plant kappa hydroxylase gene.
2. The nucleic acid according to Claim 1 wherein the transcription regulatory region is from a *Lesquerella fendleri* kappa hydroxylase gene.
3. The nucleic acid according to Claim 2 wherein the transcription regulatory region is comprised of nucleotide 1 to nucleotide 2214 of SEQ ID NO:1.
4. The nucleic acid according to Claim 1 further comprised of a coding sequence for a plant kappa hydroxylase gene.
5. A recombinant nucleic acid comprised of the nucleic acid according to Claim 1 and a heterologous gene.
6. The recombinant nucleic acid according to Claim 5 wherein the heterologous gene is an enzyme of lipid metabolism.
7. The recombinant nucleic acid according to Claim 5 wherein the heterologous gene is a plant hydroxylase

gene.

8. A host plant cell comprised of the recombinant nucleic acid according to Claim 5.

9. An expression construct comprised of a transcription regulatory region from a plant kappa hydroxylase gene and a transcription termination region.

10. The expression construct according to claim 9 wherein the transcription regulatory region is from a *Lesquerella fendleri* kappa hydroxylase gene.

11. The expression construct according to Claim 10 wherein the transcription regulatory region is comprised of nucleotide 1 to nucleotide 2214 of SEQ ID NO:1.

12. The expression construct according to Claim 9 further comprised of a translation initiation region and a translation termination region.

13. The expression construct according to Claim 9 further comprised of a coding sequence for a plant kappa hydroxylase gene.

14. The expression construct according to Claim 9

further comprised of a coding sequence for a heterologous gene.

15. The expression construct according to Claim 14 wherein the heterologous gene is an enzyme of lipid metabolism.

16. The expression construct according to Claim 14 wherein the heterologous gene is operably linked to the transcription regulatory region and the transcription termination region such that a sense transcript of the heterologous gene would be produced.

17. The expression construct according to Claim 9 wherein the transcription regulatory region is a promoter.

18. A host cell comprised of the expression construct according to Claim 9.

19. The host cell according to Claim 18 wherein the host cell is a host plant cell.

20. A host plant cell comprised of the expression construct according to Claim 14.

21. The host plant cell according to Claim 20 wherein the host plant cell is a Brassica species.

22. The host plant cell according to Claim 20 wherein the host plant cell is a dicotyledenous species.

23. A process of altering fatty acid composition of a seed comprising:

- (a) transforming a host plant cell with the recombinant nucleic acid according to Claim 6,
- (b) obtaining a seed from a collection of transformed host plant cells, and
- (c) screening the seeds for a desired composition of fatty acid.



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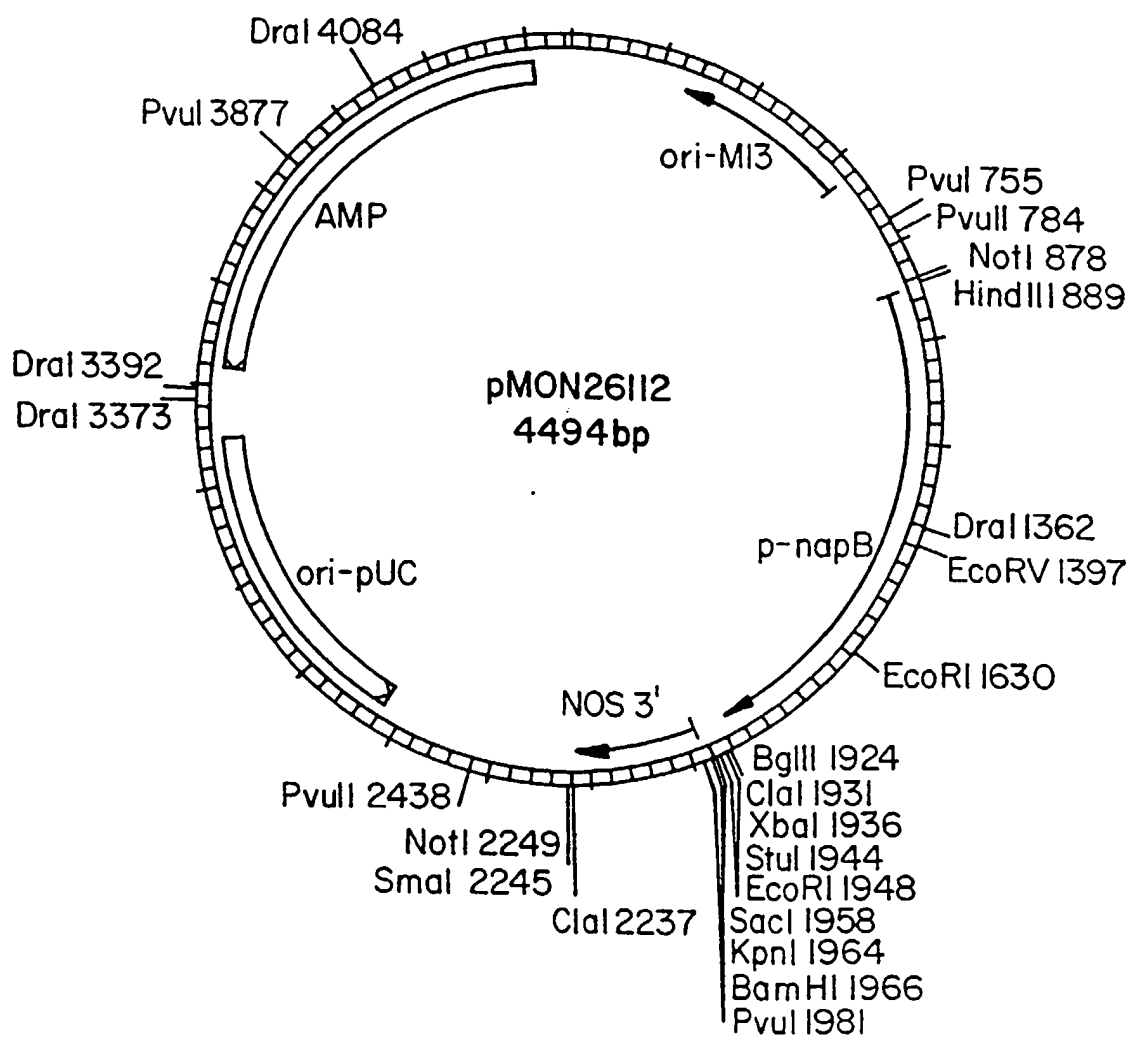


FIG. 1

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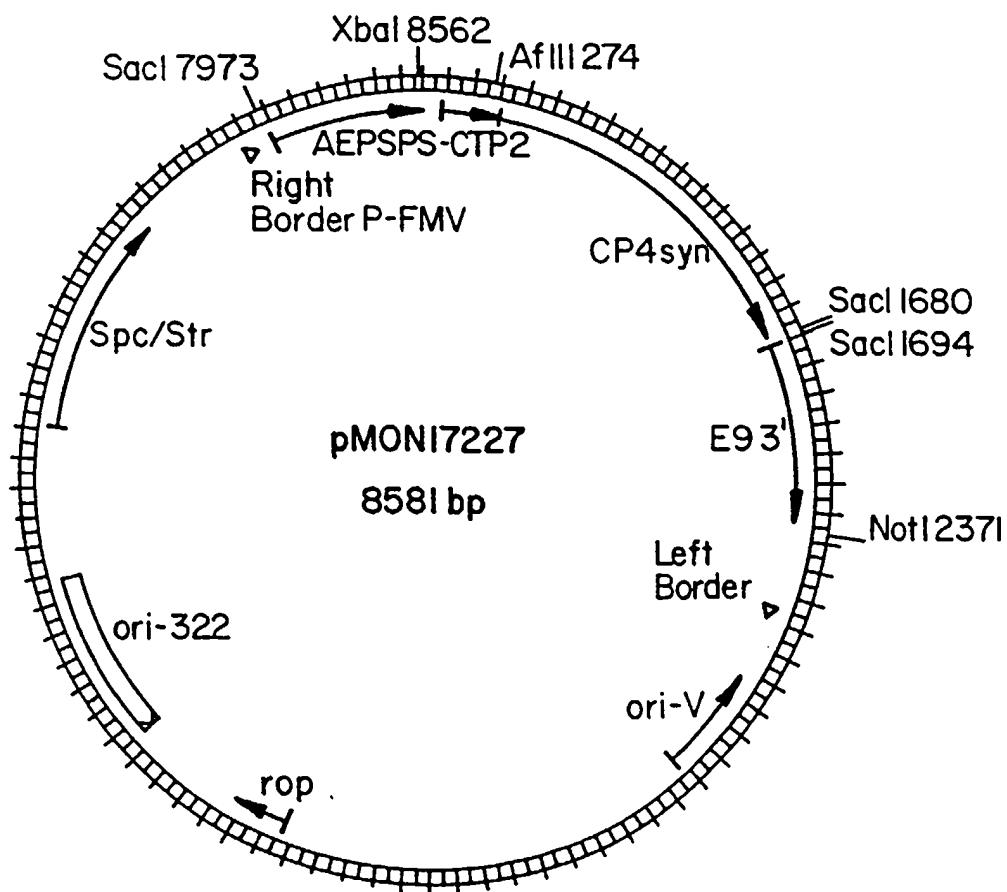


FIG. 2

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## FIG. 3

10	20	30	40	50
<u>AAGCTTTTGA</u>	GCTCATCAGT	TACTCAGGAA	GATTAAGTCT	TTGCTTGTTG
<i>HindIII</i>				
60	70	80	90	100
TCTGATTTTC	TTTAAATACA	TGAAGGATCG	GTTATGAATC	TTCTTTTTTT
110	120	130	140	150
GTGTTTTTGGG	ATTATGAAGC	TGTCTTTGGA	TATTAGTTGC	GGTTATTAGC
160	170	180	190	200
ATGCTTCTCT	TTTGTGTTTT	GGGGATTATG	AAGCAGGGTC	TGTCTATGTA
210	220	230	240	250
ATGCATTTTG	TTTGAAAAC	CAGCTAATGC	TAATGCAATT	TCTTTTGAAA
260	270	280	290	300
CCTTTGTTAT	GTTTTCGAAA	ATATTGAATA	NGTTCTGTTA	TGGATTTATT
310	320	330	340	350
TGCAAAAGCC	ATTGATTAAA	TCAAACATTA	CATAAGAACA	ACATTCATTA
360	370	380	390	400
TTAACTAATT	AGAGATGCAA	AACACAACAT	TACATACAAC	ATCAGTGACT
410	420	430	440	450
AATTATTGAG	ACAAAACAAC	ATCACATACA	CAAACATTCA	TCTCATACAT
460	470	480	490	500
CACTTAGAGA	GACACAAAAA	GCAACCAAAC	ACAACATTTC	CGGCAACAAC
510	520	530	540	550
AATTAGCTTC	ATACGTTTTG	CTTCTCCTTT	CAAGCCTTCA	ATCATCTTCT
560	570	580	590	600
CACAGCCACG	AATCTGAGCC	TTCAATAATA	ACATTTCTTC	ATCGTGACAC
610	620	630	640	650
TTCTCACGGT	TATGAATGTA	AGCCTTTATG	TCCTCTACTT	CTTCTACTAA
660	670	680	690	700
AGACACATCA	GTCCACTTCC	AGGTGTGGAA	TCCTCCTCTT	TTGAAATTTT
710	720	730	740	750
TCTCACAGGT	ATGGAATAAT	CTACCTAGGT	TTTTTGAGGT	TCTTGAGGTT
760	770	780	790	800
CTGATCACAA	CACGACATCC	AAATCGACAG	GTCTTAGGAA	AACCACGATG
810	820	830	840	850
GTTATCATCT	TCAAGCTCAC	TGTCAAAAGA	GAAAAACGAG	TTTGAAGAAG
860	870	880	890	900
AAGAAGGCAT	TATCAATTTT	AGAGAATTTT	GGAGAATTTT	GAGAGATTGA
910	920	930	940	950
GAATTGGGAA	ATAAGAACCC	TAATCCCCAA	TTTATGAGAT	TGAAAATATA
960	970	980	990	1000
TCCGTTAGAG	AAGAAACATA	ATGCTGTGCG	TTTAAATTAG	AAAAAATAGA
1010	1020	1030	1040	1050
GATGGGCTTT	ATCTTTTGTT	AAGAGTTTTG	GGCTTGGGCT	TGGGTTTTTG
1060	1070	1080	1090	1100
ATAAAAAAAT	TTAATTAAAC	CAAAACGACG	TCGTTTGGTT	TAATTGTTGT
1110	1120	1130	1140	1150
TAAAAAAAAT	TAAAACACCA	AAACGACGTC	GTTTTGGTGT	TATTAACGGC
1160	1170	1180	1190	1200
CTTAAAACGG	ATTAAATCCA	TAATCCGTCA	GTCAACTAGG	TTACGGATGG
1210	1220	1230	1240	1250
TCAACGGCGT	TTTTGCATAA	CGGAGGCACA	GTTCAGGCTT	AACGGAGTGG

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## FIG. 3 (continued)

1260	1270	1280	1290	1300
ACCGAATGGC	TTTTTAGGAA	GTTTGTAACC	GGGATTTTTT	GTTTATGATG
1310	1320	1330	1340	1350
TATTTGTCCC	CGTCGGCTAT	TGTTTAGGCC	GTTTTTCCTA	TATATTGGAA
1360	1370	1380	1390	1400
ATAACTATTG	TCCAGACGAG	TTACTTCTCC	AACATATCAA	GAAATGTTAC
1410	1420	1430	1440	1450
AAAGAAGTGT	TACAAAAATG	TGTTACTAAG	CCATAAAACT	CAAAGCATAT
1460	1470	1480	1490	1500
ATCTTAGACC	CTAAGCCTAA	ACCCTAGAAC	TTTCTAGGAC	GTTTATACCT
1510	1520	1530	1540	1550
TGTCCTTTCT	TTAGTTTCCT	TTAAAGGCCT	TCGTATTTCAT	AAGTTTATT
1560	1570	1580	1590	1600
TTTGCTTAAT	ACTAACACTA	GAAATAATCA	ACATAAACTA	GGTTAAGTCG
1610	1620	1630	1640	1650
TGGATCTAAT	TTTATTGTGA	AAATGTAATT	GCTTCTCTTA	AGAAAAGATT
1660	1670	1680	1690	1700
CATAGCAAAA	TATTCGCATC	TTTCTGTGA	ATCATCTTTT	GTTTTTGGGG
1710	1720	1730	1740	1750
CTATTAAAGA	AAAATTGAAC	TCATGAAATG	GTGACAACTT	TATTCTAGAG
1760	1770	1780	1790	1800
GTAACAGAAC	AAAAATATAG	GAACAACACG	TGTTGTTTCAT	AAACTACACG
1810	1820	1830	1840	1850
TATAATACTC	AAGAAGATGA	ATCTTTATAA	GAATTTAGTT	TTCTCATGAA
1860	1870	1880	1890	1900
AACATAAAAA	ATTTTGTCAA	TTGAAAGTGA	CAGTTGAAGC	AAAGGAACAA
1910	1920	1930	1940	1950
AAGGATGGTT	GGTGATGATG	CTGAAATGAA	AATGTGTCAT	TCATCAAATA
1960	1970	1980	1990	2000
CTAAATACTA	CATTACTTGT	CACTGCCTAC	TTCTCCTATT	TCCTCCGCCA
2010	2020	2030	2040	2050
CCCATTTTGG	ACCCACGAGC	CTTCCATTTA	AACCCTCTCT	CGTGCTATTC
2060	2070	2080	2090	2100
ACCAGAAGAG	AAGCCAAGAG	AGAGAGAGAG	AGATTGTGCT	GAGGATCATT
2110	2120	2130	2140	2150
GTCTTCTTCA	TCGTTATTAA	CGTAAGTTTT	TTTTGACCAC	TCATATCTAA
2160	2170	2180	2190	2200
AATCTAGTAC	ATGCAATAGA	TTAATGACTG	TTCCTTCTTT	TGATATTTTC
2210	2220	2230	2240	2250
AGCTTCTTGA	<u>ATTCAAGATG</u>	GGTGCTGGTG	GAAGAATAAT	GGTTACCCCC
<i>EcoRI</i>				
2260	2270	2280	2290	2300
TCTTCCAAGA	AATCAGAAAC	TGAAGCCCTA	AAACGTGGAC	CATGTGAGAA
2310	2320	2330	2340	2350
ACCACCATTC	ACTGTTAAAG	ATCTGAAGAA	AGCAATCCCA	CAGCATTGTT
2360	2370	2380	2390	2400
TCAAGCGCTC	TATCCCTCGT	TCTTCTCCT	ACCTTCTCAC	AGATATCACT
2410	2420	2430	2440	2450
TTAGTTTCTT	GCTTCTACTA	CGTTGCCACA	AATTACTTCT	CTCTTCTTCC
2460	2470	2480	2490	2500
TCAGCCTCTC	TCTACTTACC	TAGCTTGGCC	TCTCTATTGG	GTATGTCAAG

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## FIG. 3 (continued)

2510	2520	2530	2540	2550
GCTGTGTCCTT	AACCGGTATC	TGGGTCATTG	GCCATGAATG	TGGTCACCAT
2560	2570	2580	2590	2600
GCATTTCAGTG	ACTATCAATG	GGTAGATGAC	ACTGTTGGTT	TTATCTTCCA
2610	2620	2630	2640	2650
TTCCCTTCCTT	CTCGTCCCTT	ACTTCTCCTG	GAAATACAGT	CATCGTCGTC
2660	2670	2680	2690	2700
ACCATTTCCAA	CAATGGATCT	CTCGAGAAAG	ATGAAGTCTT	TGTCCCACCG
2710	2720	2730	2740	2750
AAAAAAGCTG	CAGTCAAATG	GTATGTTAAA	TACCTCAACA	ACCCTCTTGG
2760	2770	2780	2790	2800
ACGCATTCTG	GTGTTAACAG	TTCAGTTTAT	CCTCGGGTGG	CCTTTGTATC
2810	2820	2830	2840	2850
TAGCCTTTAA	TGTATCAGGT	AGACCTTATG	ATGGTTTCGC	TTCACATTTT
2860	2870	2880	2890	2900
TTCCCTCATG	CACCTATCTT	TAAAGACCGA	GAACGCCTCC	AGATATACAT
2910	2920	2930	2940	2950
CTCAGATGCT	GGTATTCTAG	CTGTCTGTTA	TGGTCTTTAC	CGTTACGCTG
2960	2970	2980	2990	3000
CTTCACAAGG	ATTGACTGCT	ATGATCTGCG	TCTATGGAGT	ACCGCTTTTG
3010	3020	3030	3040	3050
ATAGTGAAGT	TTTTCCTTGT	CTTGGAAGT	TTCTTGCAGC	ACACTCATCC
3060	3070	3080	3090	3100
TTCGTTACCT	CATTATGATT	CAACCGAGTG	GGAATGGATT	AGAGGAGCTT
3110	3120	3130	3140	3150
TGGTTACGGT	AGACAGAGAC	TATGGAATAT	TGAACAAGGT	GTTCCATAAC
3160	3170	3180	3190	3200
ATAACAGACA	CACATGTGGC	TCATCATCTC	TTTGCAACTA	TACCGCATTA
3210	3220	3230	3240	3250
TAACGCAATG	GAAGCTACAG	AGGCGATAAA	GCCAATACTT	GGTGATTACT
3260	3270	3280	3290	3300
ACCACTTCGA	TGGAACACCG	TGGTATGTGG	CCATGTATAG	GGAAGCAAAG
3310	3320	3330	3340	3350
GAGTGTCTCT	ATGTAGAACC	GGATACGGAA	CGTGGGAAGA	AAGGTGTCTA
3360	3370	3380	3390	3400
CTATTACAAC	AATAAGTTAT	GAGGCTGATA	GGGCGAGAGA	AGTGCAATTA
3410	3420	3430	3440	3450
TCAATCTTTT	TTTCATGTTT	TAGGTGTCTT	GTTTAAGAAG	CTATGCTTTG
3460	3470	3480	3490	3500
TTTCAATAAT	CTCAGAGTCC	ATTTAGTTGT	GTTCTGGTGC	ATTTTGCCTA
3510	3520	3530	3540	3550
GTTATGTGGT	GTCGGAAGTT	AGTGTTCAAA	CTGCTTCCTG	CTGTGCTGCC
3560	3570	3580	3590	3600
CAGTGAAGAA	CAAGTTTACG	TGTTTAAAT	ACTCGGAACG	AATTGACCAC
3610	3620	3630	3640	3650
AANATATCCA	AAACCGGCTA	TCCGAATTCC	ATATCCGAAA	ACCGGATATC
3660	3670			
CAAATTTCCA	GAGTACTTAG			

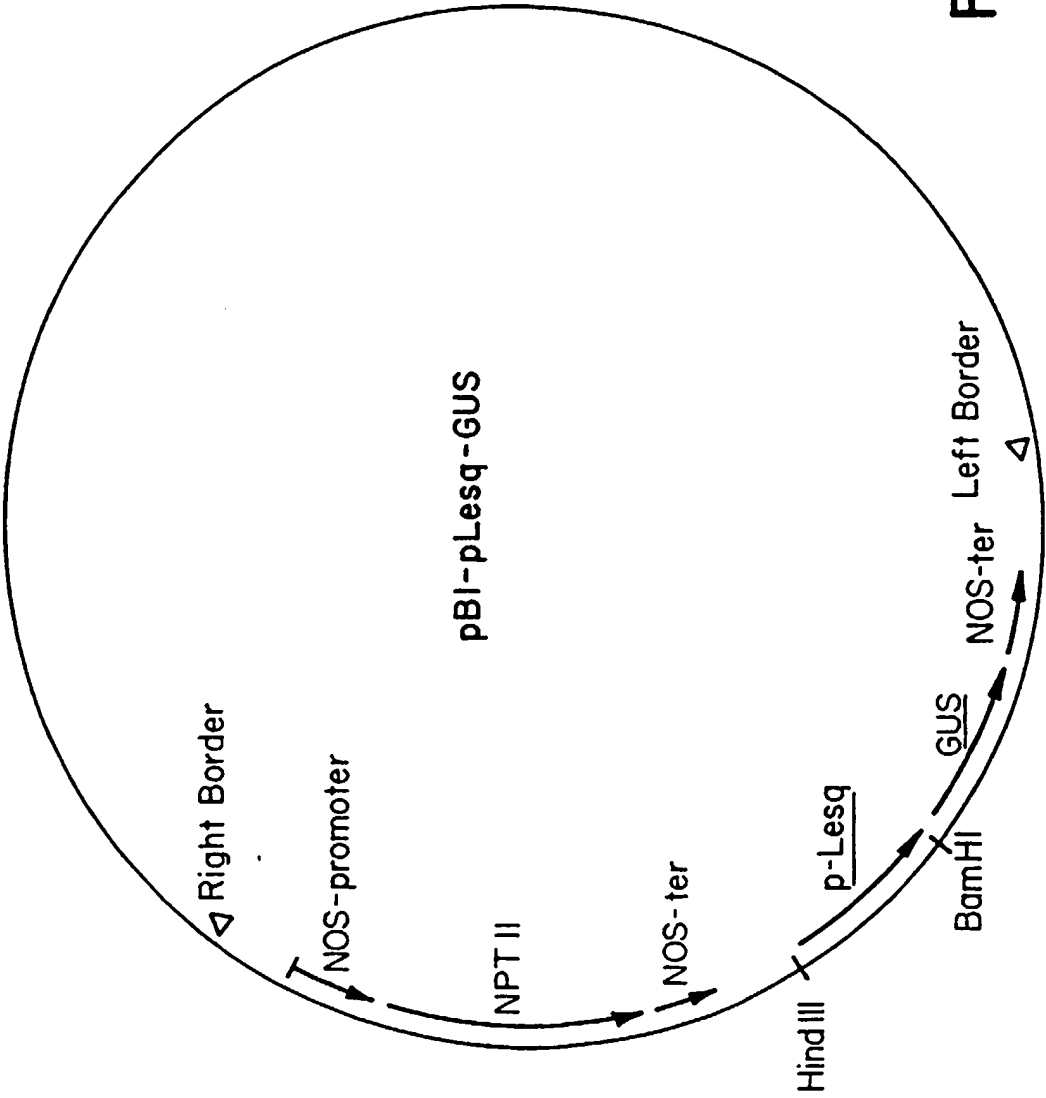


FIG. 4

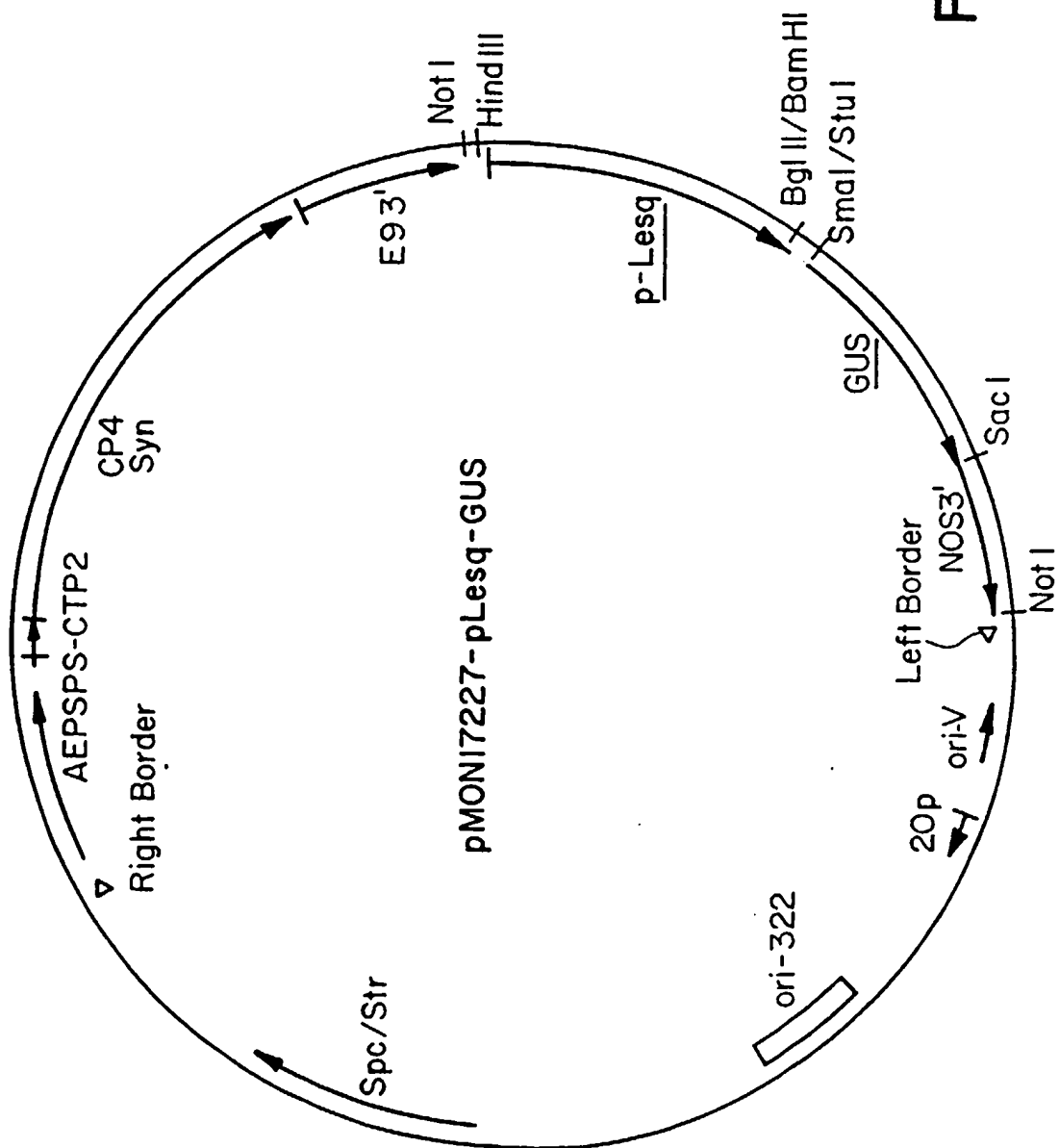


FIG. 5

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/14612**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :C12N 15/00, 15/05, 15/04, 15/11, 15/29; A01H 4/00

US CL :435/172.3, 69.1, 69.2; 935/33; 536/23.1, 23.6; 800/278

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/172.3, 69.1, 69.2; 935/33; 536/23.1, 23.6; 800/278

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

MEDLINE, CAPLUS, BIOSIS, AGRICOLA, APS

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	VAN DE LOO et al. An Oleate 12-Hhydroxylase From Ricinus Communis L. is a Fatty Acyl Desaturase Homolog. Proc. Natl. Acad. Sci. 1995, Vol. 92, pages 6743-6747, see entire document.	1-23
A	OKULEY et al. Arabidopsis FAD2 Gene Encodes the Enzyme that is Essential for Polyunsaturated Lipid Synthesis. Plant Cell. 1994, Vol. 6, pages 147-158, see entire document.	1-23

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

14 OCTOBER 1998

Date of mailing of the international search report

03 NOV 1998

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